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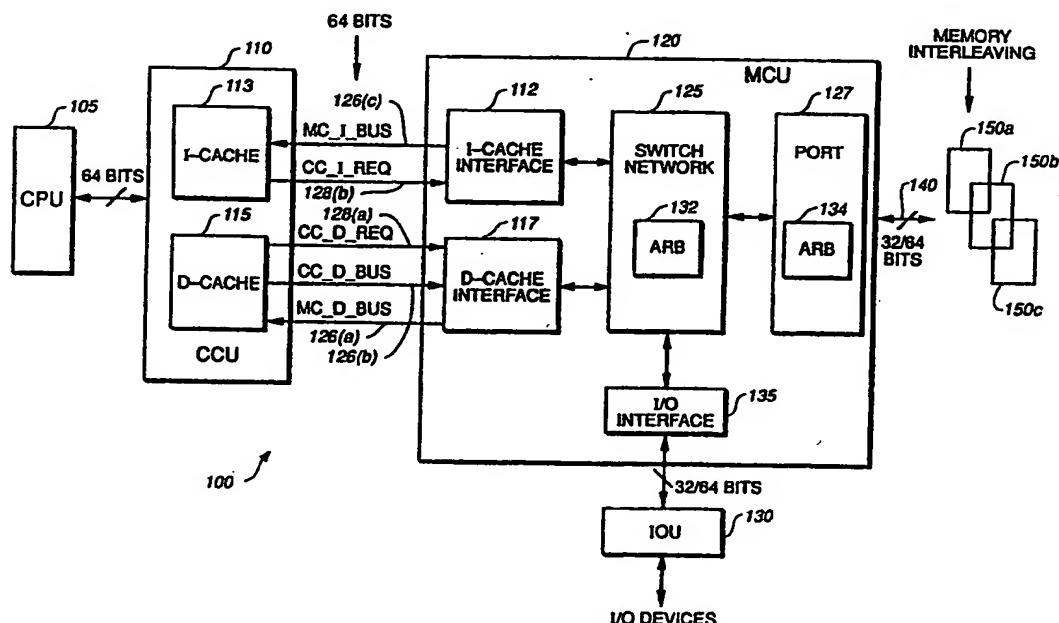
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(71) Applicant: SEIKO EPSON CORPORATION [JP/JP]; 4-1, Nishi-Shinjuku 2-chome, Shinjuku-ku, Tokyo 163 (JP).

(72) Inventors: LENTZ, Derek, J. ; 17400 Phillips Avenue, Los Gatos, CA 95032 (US). TANG, Cheng-Long ; 1915 Ribi-si Way, San Jose, CA 95131 (US).

(74) Agents: SUZUKI, Kisaburo et al.; Seiko Epson Corporation, 4-1, Nishi-Shinjuku 2-chome, Shinjuku-ku, Tokyo 163 (JP).

(54) Title: SYSTEM AND METHOD FOR SUPPORTING A MULTIPLE WIDTH MEMORY SUBSYSTEM



(57) Abstract

The present invention provides a memory system interface design, which provides access to a dual width memory bus. Specifically, a subsystem and method provides for interfacing with a 32 bit or a 64 bit bus. The 32 bit bus would be used for low end products, and the 64 bit bus would be used for high end products. A memory control unit (MCU) supports both the 32 bit and 64 bit modes. Selecting a 32 bit or 64 bit memory subsystem gives a user more room to adjust system cost and performance.

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DESCRIPTION

Title: SYSTEM AND METHOD FOR SUPPORTING A MULTIPLE WIDTH
MEMORY SUBSYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

5 The present application is related to the following application, assigned to the Assignee of the present application:

10 Microprocessor Architecture Capable of Supporting Multiple Heterogeneous Processors, invented by Derek J. Lentz et al., Attorney Ref: SP016, Application Serial No. 07/726,893, filed July 8, 1991, which is hereby incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

15 The present invention relates generally to the field of microprocessor memory systems, and more particularly to a system that supports a dual width memory bus.

2. Discussion of Related Art

20 A typical computer-based processor system (or computer system) consists of three major subsystems: a main memory, one or more central processing units (CPU) and an input-output (I/O) subsystem. In a computer system, the various subsystems must have interfaces to one another. For example, the memory and CPU need to communicate, as well as the CPU and I/O devices.

25 This communication is typically done via a bus. The bus serves as a shared communication link between the subsystems. Two major advantages of having a bus are low cost and versatility. By defining a single interconnection scheme, new devices and subsystems can easily be added to the computer system. Moreover, peripherals may even be ported between separate computer systems that use a common bus.

30 One reason bus design is so difficult is that the maximum bus speed is largely limited by physical factors: the length of the bus and the number of devices (and, hence, bus loading). These physical limits prevent arbitrary bus speedup.

35 The objective of designing a memory subsystem is to attempt to match processor speed with the rate of information (or bandwidth) of memory at the lowest level and most reasonable cost. For main memory, we can use a wider bus called a "memory bus" to increase the memory bandwidth or to reduce the latency of memory. In the case of a memory subsystem, the memory bandwidth is the number of memory bytes that can be transferred (either fetched or stored) between the CPU and the memory per unit time. Hence, the maximum memory bus bandwidth B is equal to $B=W/T_m$ byte/s, where W is the width of word in bytes delivered per memory

cycle Tm.

Oftentimes, a variety of different size memory buses are available to help increase performance. However, designing a system that allows access to multiple external buses having different widths presents a design problem. If, for example, a system that is currently configured to accept data from the memory bus in 32 bit blocks, a 64 bit data transfer will create a predicament for the CPU and/or cache. Consequently, a system is needed that allows memory buses with different widths to be utilized without changing the overall configuration of the computer system. For a more in depth discussion of the above, see Hennessy et al., *Computer Architecture a Quantitative Approach*, Morgan Kaufmann Publishers (1990).

SUMMARY OF THE INVENTION

The present invention provides a memory system interface design for a processor and a method of operating such an interface which provides access to a dual width memory bus. Specifically, the present invention provides a mechanism that allows a computer-based system to access either a 32 bit memory bus or a 64 bit memory bus. The 32 bit memory bus would be used for low-end products, while the 64 bit memory bus would be used for high-end products. A memory control unit (MCU) of the present invention supports both modes: the 32 bit bus mode and the 64 bit bus mode. The present invention in one embodiment has been integrated onto a microprocessor chip.

Selecting a 32 bit or 64 bit memory subsystem provides a user with a flexible framework in which to design a system. The user can adjust system cost and performance by choosing to utilize a 32 bit or 64 bit external bus. The present invention provides a system and method which decreases the amount of wires necessary to transfer data. Moreover, a microprocessor chip incorporating the present invention allows switching between the 32 bit or 64 bit external memory bus without changing the control signals and/or system configuration.

The present invention provides a computer-based system and method for efficiently transferring data over an external memory bus between a main memory and a bus requestor, comprising a dual width memory subsystem configured to provide access to a plurality of different external memory buses. The dual width memory subsystem comprises a plurality of multiplexers connected to receive data from the bus requestor and a storage device connected to receive and store data from the plurality of multiplexers, the data is stored in blocks depending on the width of the external bus. Furthermore, the dual width memory subsystem comprises a storage device connected to receive and store data from the external memory bus, the data is stored in blocks depending on the width of the external bus. A plurality of multiplexers connected to receive data from the storage device, and connected to

send said data to a bus requestor in blocks determined by the limitations of the system.

BRIEF DESCRIPTION OF THE DRAWINGS

5 The above and further advantages of this invention may be better understood by referring to the following description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a general block diagram of the system architecture 100 of the present invention;

10 FIG. 2 is a circuit block diagram for a cache 110 write (store) to the main memory 150;

FIG. 3a and FIG. 3b are the cache write (store) data timing for a 32 bit and a 64 bit memory bus, respectively;

15 FIG. 4 is a circuit block diagram for a read (fetch) from main memory 150 to cache 110;

FIG. 5a and FIG. 5b show return read data timing for a 32 bit and a 64 bit memory bus, respectively;

20 FIG. 6 is a detailed circuit diagram of the Data Multiplexer Select 240 shown in FIG. 2;

FIG. 7 is a general flowchart for writing a data stream to main memory 150; and

25 FIG. 8 is a general flowchart for reading a data stream from main memory 150.

DETAILED DESCRIPTION

I. Environment/Background for the Present Invention

Referring to FIG. 1, there is provided in accordance with a preferred embodiment of the present invention a microprocessor architecture designated generally as 100. System architecture 100 includes a CPU 105, a cache controller unit 110 which includes cache memories 113 and 115, an I/O subsystem 130, a memory control and interface unit 120 (MCU), and interleaved memory banks 150a, 150b, 150c configured for interleaved operations. The interleaved memory banks 150 are connected to MCU 120 via an external data bus 140. The present invention allows MCU 120 to accept data from either a 32 bit or a 64 bit external bus 140. It is contemplated that the present invention will operate in a multiprocessor environment.

Cache memory 113, 115 serves as a buffer between CPU 105 and memory 150a, 150b, and 150c. Generally, a cache is a small, fast memory located close to CPU 105 that holds the most recently accessed code or data. Typically, CPU 150 is

the fastest unit in the system, with a processor cycle typically of tens of nanoseconds, while memory 150 has a cycle time of hundreds of nanoseconds. The speed gap between CPU 105 and memory 150 can be closed by using fast cache memory 110 between the two. However, regardless of how fast CPU 105 and cache 110 are, performance will suffer if there are no means of retrieving the data in a fast, efficient manner. Consequently, connecting a wider external bus 140 to MCU 120 allows more data to be transferred. Thus, the present invention allows MCU 120 to be connected to memory buses with different data widths.

MCU 120 of a preferred embodiment of the present invention comprises a switch network 125 which includes a switch arbitration unit 132, a data cache interface circuit 117, an instruction cache interface circuit 112, an I/O interface circuit 135, and one or more memory port interface circuits 127 known as ports, each port interface circuit 127 includes a port arbitration unit 134. MCU 120 is a circuit whereby data and instructions are transferred (read or written) between cache controller unit 110 (CCU) (both D-cache 115 and I-cache 113 (read only)), IOU 130 and main memory 150.

Switch network 125 is a means of communicating between a master and slave device. To switch network 125 the possible master devices are a D_Cache 115, an I_Cache 113, or an I/O Controller Unit (IOU) 130 and the possible slave devices are a memory port 127 or an IOU 130, for example.

The function of switch network 125 is to receive the various instruction and data requests from CCU 110 and IOU 130. These units may be referred to as bus requestors. After having received these requests, the switch arbitration unit 132 passes them to the appropriate memory port (depending on the instruction address). The port 127, or ports as the case may be, will then generate the necessary timing signals, and send or receive the necessary data to/from external memory bus 140. Memory interface port 127 manages the data by sending to and receiving from interleaved memory 150. D-cache 115 requires that any data transaction be carried out in 64 bit blocks, regardless of whether the system is currently coupled to a 32 or 64 bit external memory bus 140.

Switch network 125 is connected to CCU 110, IOU 130, and memory port 127 via a set of tri-state buffered signal buses. The tri-state buffered signal buses include a memory control data bus (MC_D_BUS) 126(a), a cache data bus (CC_D_BUS) 126(b), and a memory control instruction bus (MC_I_BUS) 126(c). Furthermore, the present invention includes request buses CC_D_REQ 128(a) and CC_I_REQ 128(b) and control signals (not shown) MC_D_REQ_ACK, MC_D_DA_ACK, and MC_D_B_VLD.

Generally, a bus transaction includes two parts: sending the address and receiving or sending the data. Bus transactions are usually defined by what they do

to memory: a read transaction transfers data from memory (to either the CPU or an I/O device, for example), and a write transaction writes data to the memory. In a read transaction, the address is first put on the memory address bus (not shown) to memory 150, together with the appropriate control signals indicating a read. The 5 memory responds by returning the data on bus 140 with the corresponding control signals. A write transaction requires that the CPU or I/O device send both address and data, and requires no return of data.

The present invention contemplates being placed on a chip with either a 64 pin or a 32 pin external memory bus interface. As will be appreciated, the 64 pin 10 interface can be used in either 32 or 64 bit mode (i.e., with either a 64 bit or 32 bit external bus 140). A chip with a 32 pin memory data bus interface can not operate in 64 bit mode.

At reset, a preferred embodiment will assume a 32 bit memory interface 15 during power up (boot), read a word from a fixed location (on or off chip) and ascertain therefrom the configuration required for proper system operation. In particular, during power up CPU 105 reads and executes boot code. The boot code instructs CPU 105 to read a specific memory location in memory 150. That memory location would have encoded in it the information to determine what size data bus is coupled 20 to system 100. An alternative embodiment, includes pre-programming the chip hardware with the size of external bus 140. Thus, the sub-systems described below for allowing access to a 32 bit or 64 bit external memory bus 140 are aware, immediately after the chip is powered up or after a hardware reset, which size 25 external bus 140 is currently coupled to system 100. Of course, other means for determining the size of the external bus will be apparent to those skilled in the art and in no way is the present invention limited to the techniques described above.

Referring to FIG's. 1, 2, and 4, CC_D_BUS 126(b) and SW_WD 215, are used 30 to send write data from the master device (e.g., D_cache 115) to a write data FIFO 230 (described below and shown in FIG. 2). MC_D_BUS 126(a), SW_RD 450 and 455 are used to send the return read data from the slave device (memory port 127 or IOU 130) back to the master device. Both SW_WD and SW_RD are both tri-state buses.

II. The Dual Width Memory Subsystem

The present invention allows the system architecture described above to be interfaced with either a 32 or 64 bit external memory bus 140.

35 In order to facilitate dual width memory transfers, the present invention is designed to use a maximum of two clock cycles to send a word between cache 110 and memory interface port 127, or vice versa. For example, if cache 110 writes one long word (64 bits), and the system 100 is coupled to a 32 bit external bus 140, it will take two clock cycles to send the data to memory interface port 127.

Referring to FIG. 2, there is a logic design 200 (hereinafter subsystem 200) for writing to main memory 150. Subsystem 200 represents the hardware necessary for either a 32 or 64 bit data transfer. Subsystem 200 transfers data in a "double pumped" fashion. For example, instead of transferring one word of data every clock cycle, the subsystem 200 can transfer one half word of data every half clock cycle. Since the buses are double-pumped, care is taken in the circuit design to ensure that there is no bus-conflict when the buses turn around and switch from one master to a new master. Double pumping reduces the number of required bit lines thereby minimizing expensive wire requirements with minimal performance degradation.

5 Although the preferred embodiment implements a double pumping scheme, double pumping is not necessary for carrying out the present invention.

10

Subsystem 200 uses multiplexers 210, 220 to send data from data cache bus (CC_D_BUS) 126(b) to main memory 150. Multiplexers 210, 220 of a preferred embodiment of the present invention uses multiplexer/latches. In other words the 15 multiplexers can temporarily store data. 16 or 32 bits (depending on whether there is a 32 or 64 bit memory bus 140, respectively) of data will be transferred to memory interface port 127 every half clock cycle and stored in a write data FIFO 230, located between memory interface port 127 and CCU 110.

Subsystem 200 also contains a buffer 250 and pad 260. Buffer 250 is a tri-state output pad buffer to drive the external memory data bus and pad 260 is used to 20 connect subsystem 200 to main memory 150.

FIG's. 3(a) and 3(b) show a pair of timing diagrams for writing data to memory 150 with either a 32 bit memory bus or a 64 bit memory bus, respectively. Data can be transferred in one cycle if a 64 bit memory bus is used, while it takes two cycles to 25 transfer data using a 32 bit memory bus.

Specifically, FIG. 3(a) shows a timing diagram for writing data to memory 150 with a 32 bit memory bus. Initially, cache 110 sends a request via the cache request signal (CC_D_REQ) 128(a) for access to memory 150, shown at reference number 310. MCU 120 acknowledges that request when MC_D_REQ_ACK goes high (at the 30 rising edge of clock 305), as shown at reference number 315. Next, if access to memory is granted, the data to be written to memory 150 appears on the CC_D_BUS 126(b), as shown at reference number 320. Once the data appears on the CC_D_BUS 126(b), the data is transferred to write data FIFO 230 during the next two clock 305 cycles. The MC_D_DA_ACK signal indicates, as shown at 35 reference number 325, that the data is currently being received in write data FIFO 230. Every time 32 bits of data enters MCU 120 it is placed in write data FIFO 230.

The first 32 bits are sent during the first clock 305 cycle (15 bits per half clock cycle) and the second 32 bits are sent during the second clock 305 cycle. Referring to FIG. 2, initially, all 64 bits of data act as inputs into multiplexers 210 and 220.

During the first clock 305 cycle, the first 32 bits are selected from multiplexers 210, 220 and saved via SW_WD 215, 217 in write data FIFO 230. During the second clock cycle, the second 32 bits are selected from multiplexers 210, 220 and saved in write data FIFO 230 via SW_WD 215, 217. Those skilled in the relevant art will readily be capable of generating the necessary control signals/logic for multiplexers 210, 220 based on the disclosed timing signals described above and the information that the system 100 is currently coupled to a 32 bit external bus. Once the data is saved in write data FIFO 230, it can be written (stored) to memory 150 whenever external data bus 140 becomes available.

Oftentimes, not all of the data needs to be written to memory 150 (e.g., during a read-modify-write). Consequently, a data multiplexer select 240 is provided. Referring to FIG. 6(a), data multiplexer select 240 provides a scheme for selecting a set of bytes from the data being transferred from write data FIFO 230 to main memory 150. During a read-modify-write, potentially only a portion of the data is modified. For example, as shown in FIG. 6(b) only the first 8 bits of W0 have been modified (as indicated by shading). Initially, all 32 bits are placed at inputs ORG0 660 through ORG3 666 of multiplexers A 610 through D 640. The data at these inputs is the data originally read from the read portion of the read-modify-write operation. This data is modified and placed at the other inputs NEW0 650 through NEW3 656 of multiplexers A 610 through D 640. As illustrated in this example, only the first 8 bits have been modified, the remaining 24 bits of data should not be stored into memory. Thus, data line NEW0 650 is selected in multiplexer A 640 and data lines ORG1 662, ORG2 6664, and ORG3 664 are selected in multiplexers B 630, C 640, and D 650. Which has the effect of storing the data as originally read from memory except for the modified portion of the data. The structure and operation of the control logic for selecting the outputs of multiplexers A 640 through B 660 will become apparent to those skilled in the art.

Note that the data multiplexer select 240 is not essential to practice the present invention. It is only an option that has been implemented in a preferred embodiment of the present invention.

The timing diagram shown in FIG. 3(a) shows an example of two 64 bit words being written to memory 150 via a 32 bit external bus 140. A sample write data FIFO 340 is shown with four 32 bit blocks. At this point, the data is ready to be sent on external data bus 140 in 32 bit blocks from write data FIFO 340.

FIG. 3(b) shows the timing diagram for writing data to main memory 150 with a 64 bit external memory bus 140. Initially, cache 110 requests an acknowledgement from MCU 120 that it can write data to memory 150. Once again, this is accomplished by sending CC_D_REQ high at 350. MCU 120 acknowledges the request by sending MC_D_REQ_ACK high at 355, at which point the data is sent

onto the CC_D_BUS 126(b). At the beginning of the next clock cycle (shown at reference number 365) 32 bits of data are transferred to write data FIFO 230 via lines SW_WD 215, 217. Once again, the MC_D_DA_ACK signal goes high to acknowledge that write data FIFO 230 is receiving the data from cache 110.

5 In contrast to the 32 bit memory bus timing constraints, it only takes one clock cycle to transfer the 64 bits to write data FIFO 230. 32 bits are transferred every half cycle. A sample write data FIFO 375 is shown with two 64 bit blocks. At this point, the data is ready to be driven onto external data bus 140 in 64 bit blocks.

10 Referring to FIG. 2, as stated above, all 64 bits of data act as inputs to multiplexers 210 and 220. When a 64 bit external data bus 140 is coupled to system 100, all 64 bits of data are selected from multiplexers 210, 220. Thus, 64 bit blocks are stored in write data FIFO 230. During the first half clock cycle the first 32 bits are placed on SW_WD 215 and during the second half clock cycle the second 32 bits are placed on SW_WD 217. Consequently, it only takes one clock cycle to transfer 15 64 bits from cache 110 to write data FIFO 240.

15 The above procedures discussed above for writing a 32 bit or 64 bit data stream to main memory 150 via external data bus 140 is generally outlined in FIG. 7. Note that the procedure is exactly the same for both 32 and 64 bit data transfers, except step 750. If system 100 is coupled to a 32 bit external bus then the data transfer takes two cycles and if system 100 is coupled to a 64 bit external bus then the data transfer takes only one cycle. Since the 32 bit only implementation is a subset of the 64 bit implementation, the same MCU 120 control logic can be used in both. MCU 120 control is designed to change the control signals (i.e., inputs to the multiplexers) according to the width of memory bus 140. Those skilled in the art will readily be capable of generating the necessary control logic to operate the present invention given the timing and hardware configuration described above.

20 FIG. 4 shows the memory system for reading data (i.e., an information fetch). In a similar fashion to a write operation, cache 110 requires that data be returned back to cache 110 in 64 bit blocks. If memory port 127 returns a two long-word read request to cache 110, it will take two clock 505 cycles to send 128 bits to cache 110. The SW_RD bus 450, 455 is used to send the return read data from the slave device (memory port 127 or IOU 130) back to the master device. This bus is not double-pumped because of the timing constraints of cache 110. Data is sent only when clock 505 is high. Cache 110 requires that the data be valid at the falling edge of 25 clock 505. Since the data is received from the port 127 when clock 505 is high, if the SW_RD bus 450, 455 was double-pumped, the earliest that cache 110 would get the data would be at the positive edge of clock 505, not at the negative edge of clock 505. Since the SW_RD bus 450, 455 is not double-pumped, this bus is only active (not tri-state) during clock 505 and there is no problem with bus buffer conflict where two

bus drivers drive the same wires at the same time.

Subsystem 400 also contains a buffer 440 and pad 450. Buffers 440 and 450 are used to translate the external pad voltages to the internal logic voltages and pad 450 is used to connect subsystem 400 to main memory 150.

5 FIG. 5(a) and FIG. 5(b) show the read data timing back to cache 110 for 32 bit and 64 bit bus modes, respectively. FIG. 5(a) shows the timing diagram for reading data from main memory 150 using a 32 bit external memory bus 140. Initially, 32 bits of data are transferred over external memory bus 140 and placed in read data FIFO 430 in 32 bit blocks. Next, the data is placed on data lines SW_RD as shown at 10 reference numbers 510 and 512. When MC_D_B_VLD goes high, as shown at reference number 515, the MC_D_BUS is available. The data/instruction requested by cache 110 will subsequently appear on data bus (MC_D_BUS) 126(a)/instruction bus (MC_I_BUS) 126(c), respectively, subsequent to the beginning of the next clock 505 rising edge, as shown at reference number 520. At this point, the data is being 15 transferred to cache 110.

Referring to FIG. 1 and 4, when utilizing a 32 bit external bus 140 the data enters MCU 120 through port 127. The data is then stored in read data FIFO 430 in 32 bit blocks. Initially, read data FIFO 430 is empty and data lines 450, 455 are available. However, once data lines SW_RD[31:0] 450 and SW_RD[63:32] 455 20 become unavailable, the data remains stored in read data FIFO 430 until the data lines 450, 455 become available (only data line 450 is used in 32 bit mode).

25 As soon as data line 450 becomes available, the first 32 bits in read data FIFO 430 are sent to multiplexers 410, 420. Specifically, multiplexer 420 is concerned with the lower 32 bits and multiplexer 410 is concerned with the higher 32 bits. The first 32 bits are popped from read data FIFO 430 and placed at the input of multiplexer 420 via SW_RD[31:0] 450. Next, the second set of 32 bits will be popped from read data FIFO 430 and sent to multiplexer 410 via SW_RD[63:32] 455. Once all 64 bits of data are placed at the inputs of multiplexers 410, 420, all 64 bits are selected from multiplexers 410, 420, and placed on MC_D_BUS 126(a) (or MC_I_BUS 126(c) as 30 the case may be) and read into cache 110.

An alternative embodiment of the present invention can be configured with a separate set of multiplexers, one set for the I_Cache 113 and the a second set for D_Cache 115. In addition, data line SW_RD[63:32] is optional for 32 bit (low cost) implementations.

35 Referring to FIG. 5(b), a timing diagram for reading data when a 64 bit external bus 140 is being utilized is shown. Initially, the data from external data bus 140 is stored in read data FIFO 430. Since a 64 bit external data bus 140 is being used, the data is stored in read data FIFO 430 is 64 bit long words. The data remains in read data FIFO 430 until data lines SW_RD 450, 455 are available. Once SW_RD

450, 455 become available, all 64 bits are transferred to the inputs of the multiplexers via SW_RD 450, 455, as shown at reference number 550. When MC_D_B_VLD goes high, as shown at 555, the data will subsequently be placed on MC_D_BUS 126(a) (or MC_I_BUS 126(c) as the case may be) during the next cycle 5 of clock 505, as shown at reference number 560. The data is transferred over MC_D_BUS 126(a) and forwarded to requesting cache 110.

Referring again to FIG. 4, after the data enters read data FIFO 430 and data lines 450, 455 are available, all 64 bits of data are placed at the inputs of multiplexers 410, 420. The lower 32 bits are placed at the input to multiplexer 420 via data line SW_RD[31:0] 450. The upper 32 bits are placed at the input to multiplexer 410 via data line SW_RD[63:32] 455. After all 64 bits have been placed 10 on data lines SW_RD[31:0] 450 and SW_RD[63:32] 455, the data is selected from multiplexers 410, 420 and forwarded to cache 110.

The procedures discussed above for reading a 32 bit or 64 bit data stream from 15 main memory 150 via external data bus 140 is generally outlined in FIG. 8. Once again note that the procedure is exactly the same for both 32 and 64 bit data transfers, except steps 850, 860, and 870. If system 100 is coupled to a 32 bit external bus then the data transfer takes two cycles per long word (64 bits) and if system 100 is coupled to a 64 bit external bus then the data transfer takes only one 20 cycle per long word. Those skilled in the art will readily be in a position to generate the necessary control logic to operate the present invention given the timing and hardware configuration described above.

Data is put into read data FIFO 430 when the switch read bus (SW_RD) is not 25 available. Data is always put in write data FIFO 230 and read out according to memory timing requirements. If external bus 140 or SW_RD buses are currently being used by some other port, the oncoming write or read data is temporarily pushed into write data FIFO 230 or read data FIFO 430, respectively. When the requested bus becomes available (i.e., external bus 140 or SW_RD is released), data is popped 30 from the particular FIFO and transferred to either memory 150, or requesting cache 110 or IOU 130. On the other hand, if the requested bus is available when the data arrives in the write data FIFO 230 or read data FIFO 430, then the data is immediately transferred through the respective FIFO onto the data lines.

The memory system is designed to allow a 64 bit data path to operate in either 35 64 or 32 bit mode. Software can select which system configuration is used. The 32 bit mode control operation for both 64 and 32 bit chips is the same. Essentially, the control logic and the data path is similar to when the system is configured to connect to a 32 bit external bus and run in 32 bit mode. However, when a 32 bit external bus is used the upper bits of the switch 125 and the write data FIFO 230 or read data FIFO 430 are not used (i.e., SW_WD[31:16] and SW_RD[63:32] will be "don't care").

But as discussed above, the control logic remains the same.

To fully appreciate the design of the present invention the write data FIFO 230 and read data FIFO 430 must be able to store at least two sets of data at any given time, where a set of data is equal to the maximum block of data that is to be transferred. This ensures that when external bus 140 has been accessed on the first set of data is being placed onto external bus 140, a second set of data is immediately available to be put on external bus 140. Thus, there is no guaranteed lag time between the first set of data being placed on external bus 140 and the second set of data being placed on external bus 140.

In addition, the present invention is directly scalable (e.g. 64/128 bits). Consequently, one skilled in the art can readily design a system that provides for dual width memory bandwidth with a variety of bit transfer combinations. In addition, the present invention contemplates a multiple width memory bus. Thus, it is contemplated that one skilled in the art could readily design a system, utilizing the teachings of the present invention described above, that is configured to handle, for example, a 32 bit, 64 bit, and/or 128 bit external data buses. Thus, there are infinite combinations of external data bus widths that could be implemented into one system with the teachings of the present invention.

It is contemplated that one skilled in the art can apply the teachings of the present invention to any type of bus in a computer-based system. For example, the present invention is applicable to dual width I/O buses. Furthermore, the present invention is not limited to external buses, but can be applied to internal buses as well.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

C L A I M S

What is claimed is:

1. A dual width memory subsystem, configured to provide access to a plurality of different width buses in a computer-based system, for efficiently transferring data between a memory and one or more bus requestors over the bus currently coupled to the system, said dual width memory subsystem comprising:

5 (a) means for determining the width of the bus currently coupled to the computer-based system;

10 (b) selecting means, configured to receive data from said bus requestor, and for selecting blocks of said data to be outputted; and

(c) storage means for receiving and storing said outputted data in blocks corresponding to said determined width;

15 wherein said selecting means permits said dual width memory subsystem to access buses having different widths.

2. The system of claim 1, further comprising:

15 (d) a selecting means for selecting individual bytes for transfer to the memory.

20 3. The system of claim 1, wherein the bus requestor is a data cache or an instruction cache or an I/O device.

25 4. The system of claim 1, further comprising bus means, located between said selecting means and said storage means, for transferring said data, and said bus means is configured for passing data during each clock phase to said storage means.

5. The system of claim 1, wherein the subsystem operates in a multiprocessor environment.

30 6. The system of claim 1, wherein said selecting means comprises a plurality of multiplexers.

35 7. A dual width memory subsystem, configured to provide access to a plurality of different width buses in a computer-based system, for efficiently transferring data between a memory and one or more bus requestors over the bus currently coupled to the system, said dual width memory subsystem comprising:

(a) means for determining the width of the bus currently coupled to the computer-based system;

(b) temp means for receiving and storing data from the bus in blocks

corresponding to said determined width; and

(c) selecting means, connected to receive data from said temp means, and connected to send said received data to said bus requestor in blocks corresponding to the limitations of the computer-based system.

5

8. The system of claim 7, wherein said bus requestor is a data cache or an instruction cache or an I/O device.

10 9. The system of claim 7, wherein said subsystem operates in a multiprocessor environment.

10 10. The system of claim 7, further comprising control means for allowing data to be transferred in at most two clock cycles.

15 11. A method for efficiently writing data to a memory from a bus requestor over a bus in a computer-based system, the computer-based system is configured to allow access to a plurality of different width buses, the method comprising the steps of:

20 (1) determining the width of a bus coupled to the computer-based system;

(2) requesting access to said memory;

(3) sending a data stream to the inputs of a plurality of multiplexers;

(4) selecting data from said data stream and storing said selected data into a temporary FIFO in blocks equal to the width of said bus; and

25 (5) popping data from said FIFO and placing it on said bus once said bus is available.

30 12. The method of claim 11, wherein during said step (3) said data stream is transferred during each clock phase into said write data FIFO.

30

13. The method of claim 11, further comprising a step of selecting which of said popped data will be transferred to memory.

35 14. A method of efficiently reading data from a memory location requested by a bus requestor in a computer-based system, the computer-based system is configured to allow access to a plurality of different width buses, the method comprising the steps of:

(1) determining the width of a bus coupled to the computer-based system;

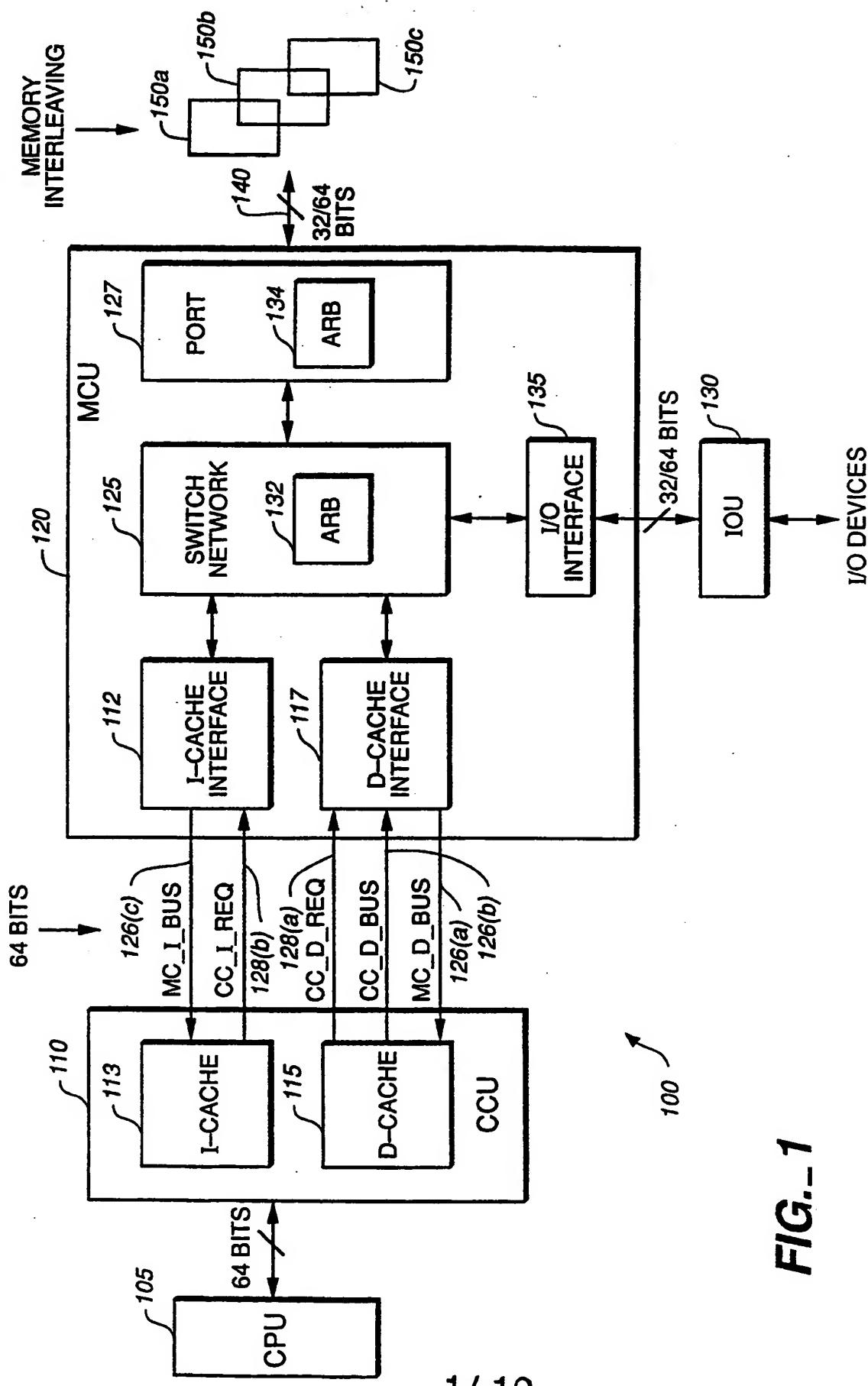
- (2) requesting access to said memory;
- (3) placing a data stream on said bus once access is granted to said memory;
- 5 (4) placing said data stream from said bus into a FIFO in blocks equal to the width of said bus;
- (5) popping data from said FIFO and placing it at the inputs to a plurality of multiplexers; and
- (6) sending said data located in said plurality of multiplexers to the bus requestor.

10

15. A method for efficiently transferring data over a bus between a memory and one or more bus requestors in a dual width memory subsystem configured to provide access to a plurality of different width buses in a computer-based system, said method comprising the steps of:

15

- (1) determining the width of a bus coupled to the computer-based system;
- (2) selecting blocks of data to be stored in a temporary FIFO corresponding to the width of said bus as determined by step (1) and receiving and storing said selected data in said temporary FIFO; and
- (3) writing said selected data stored in said temporary FIFO to said memory.



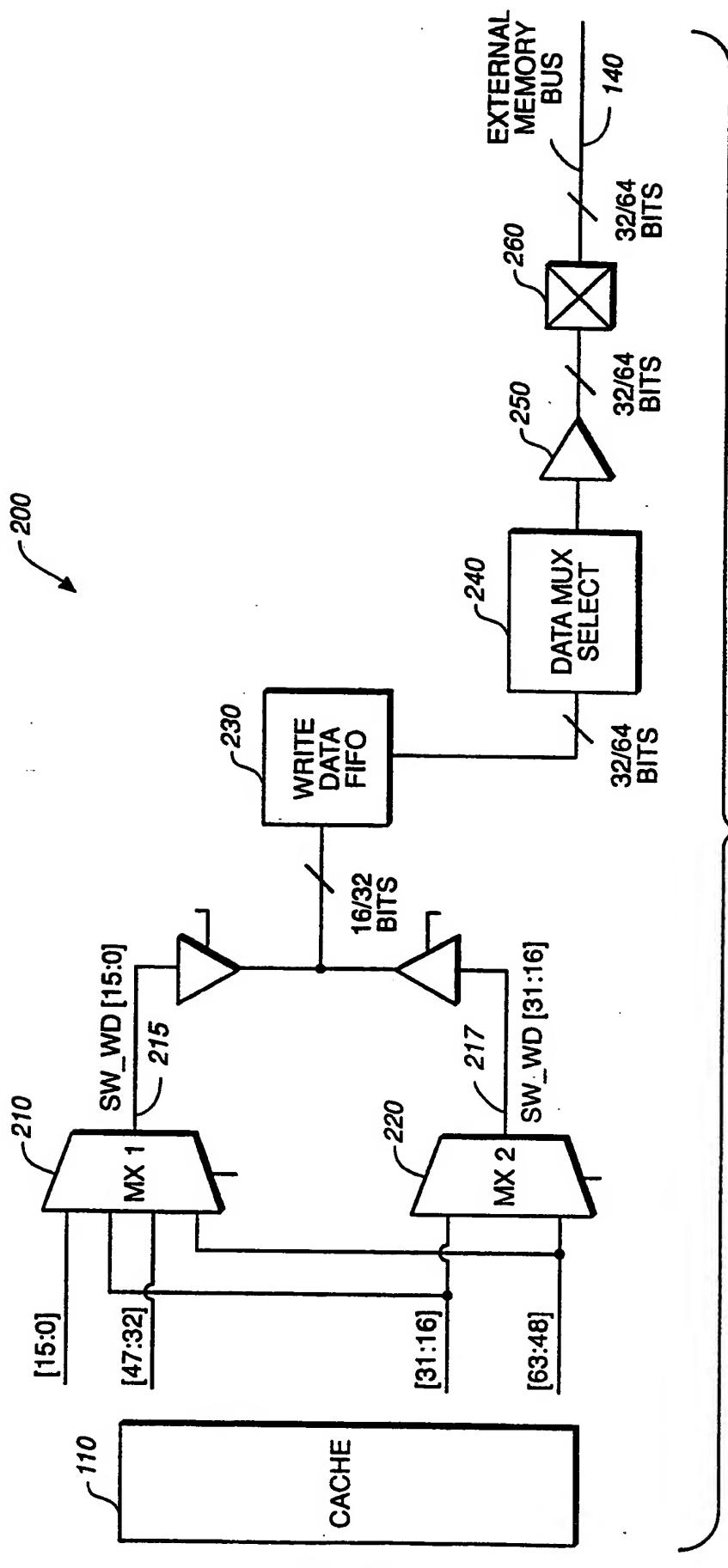


FIG. 2

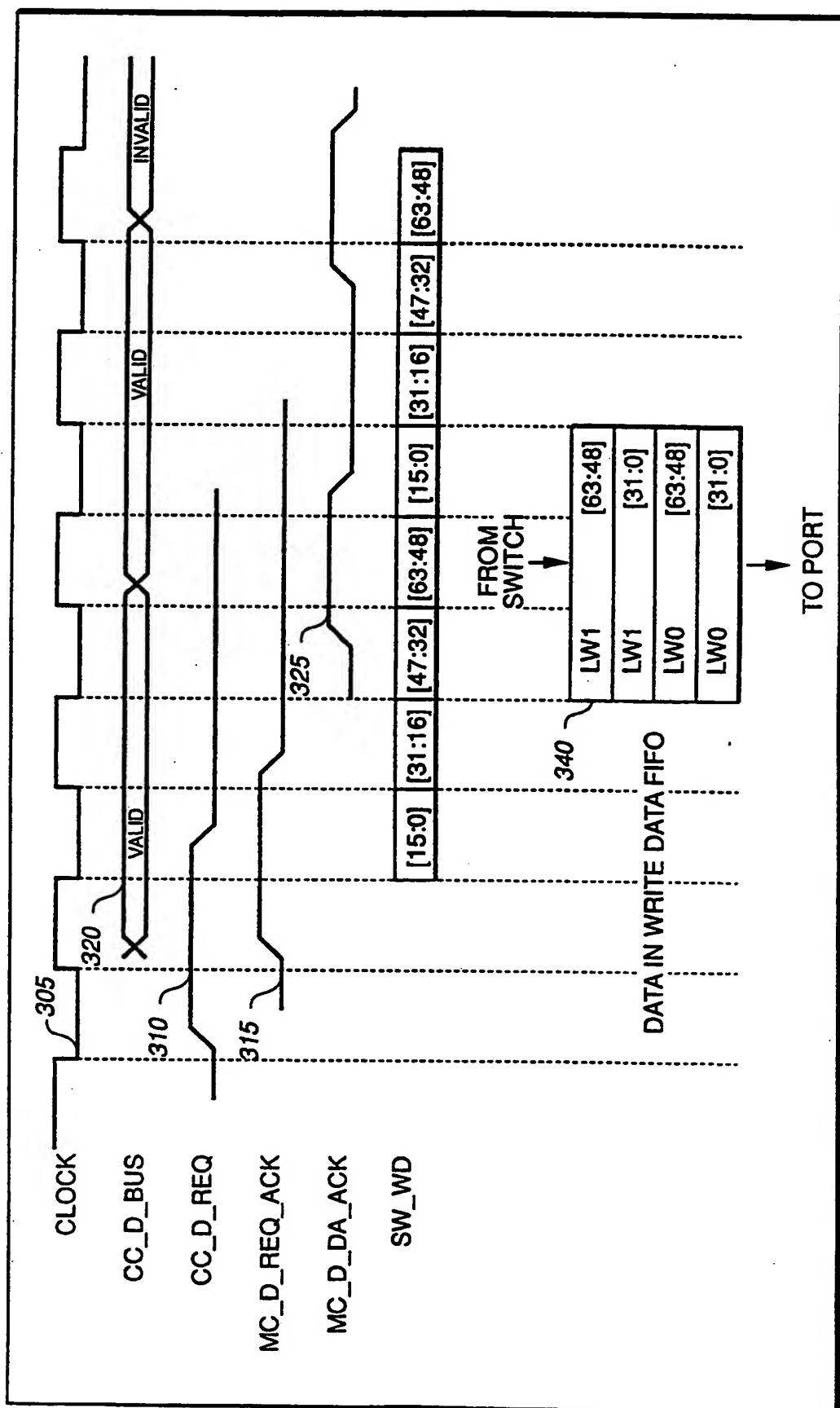
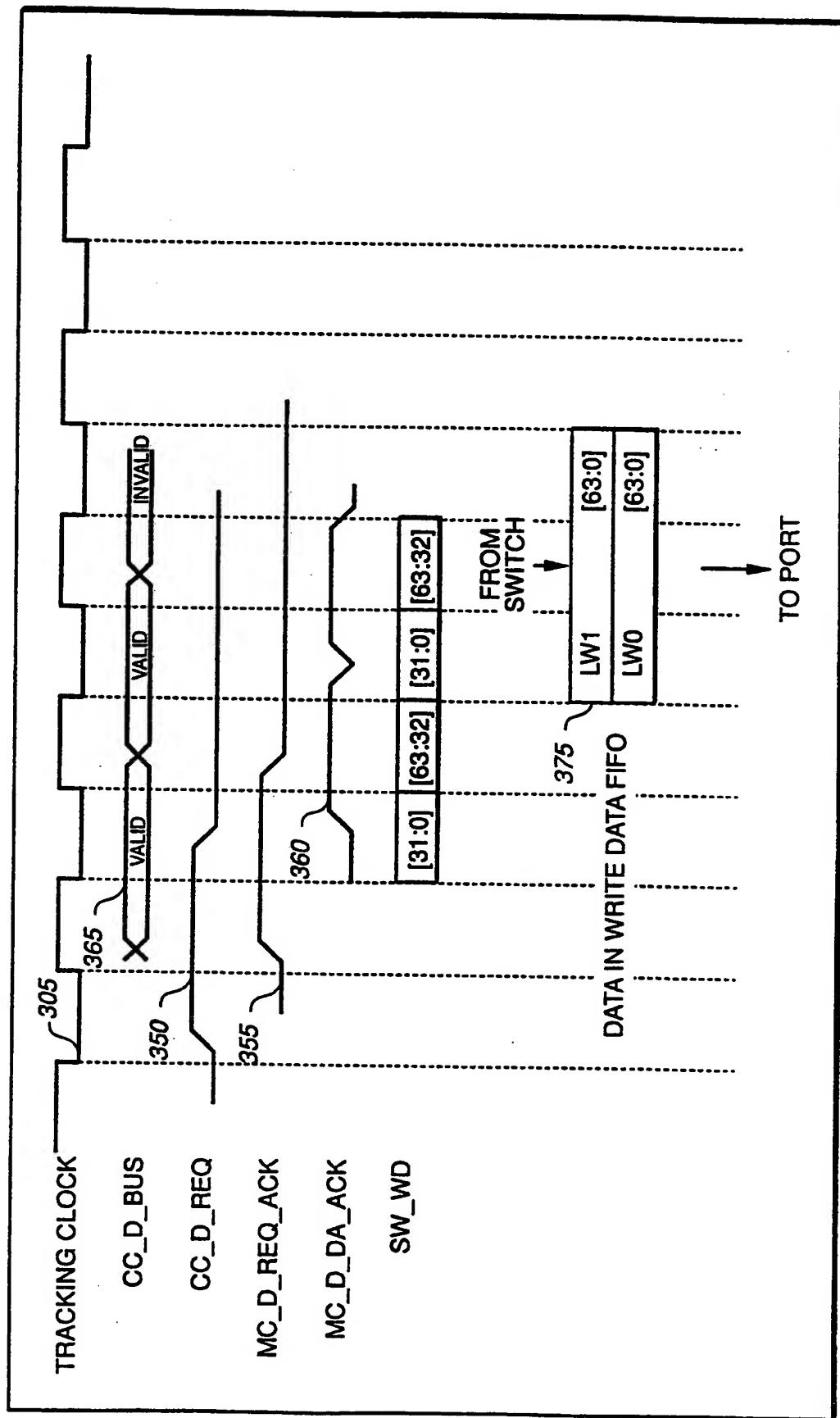
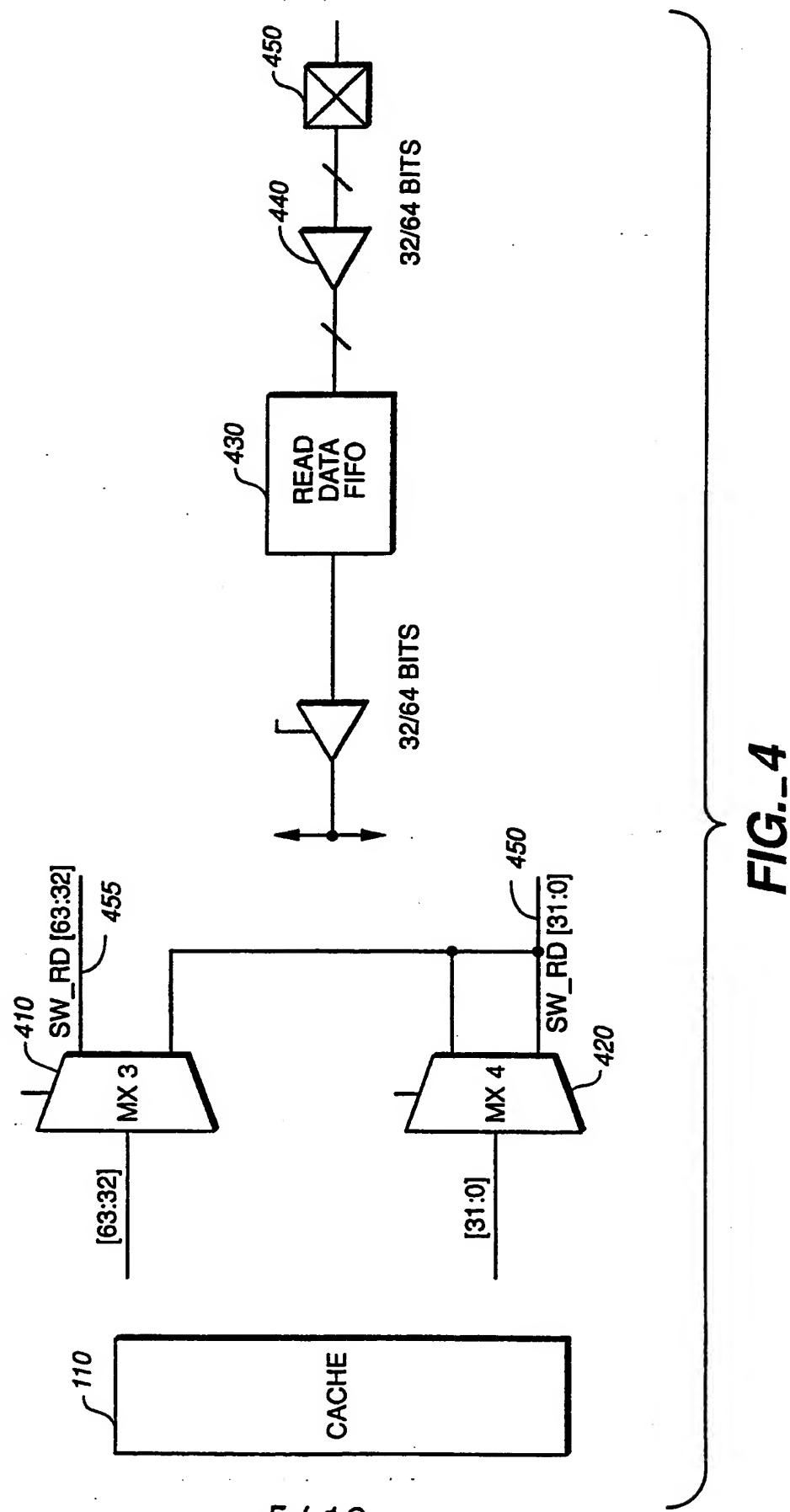


FIG. 3A





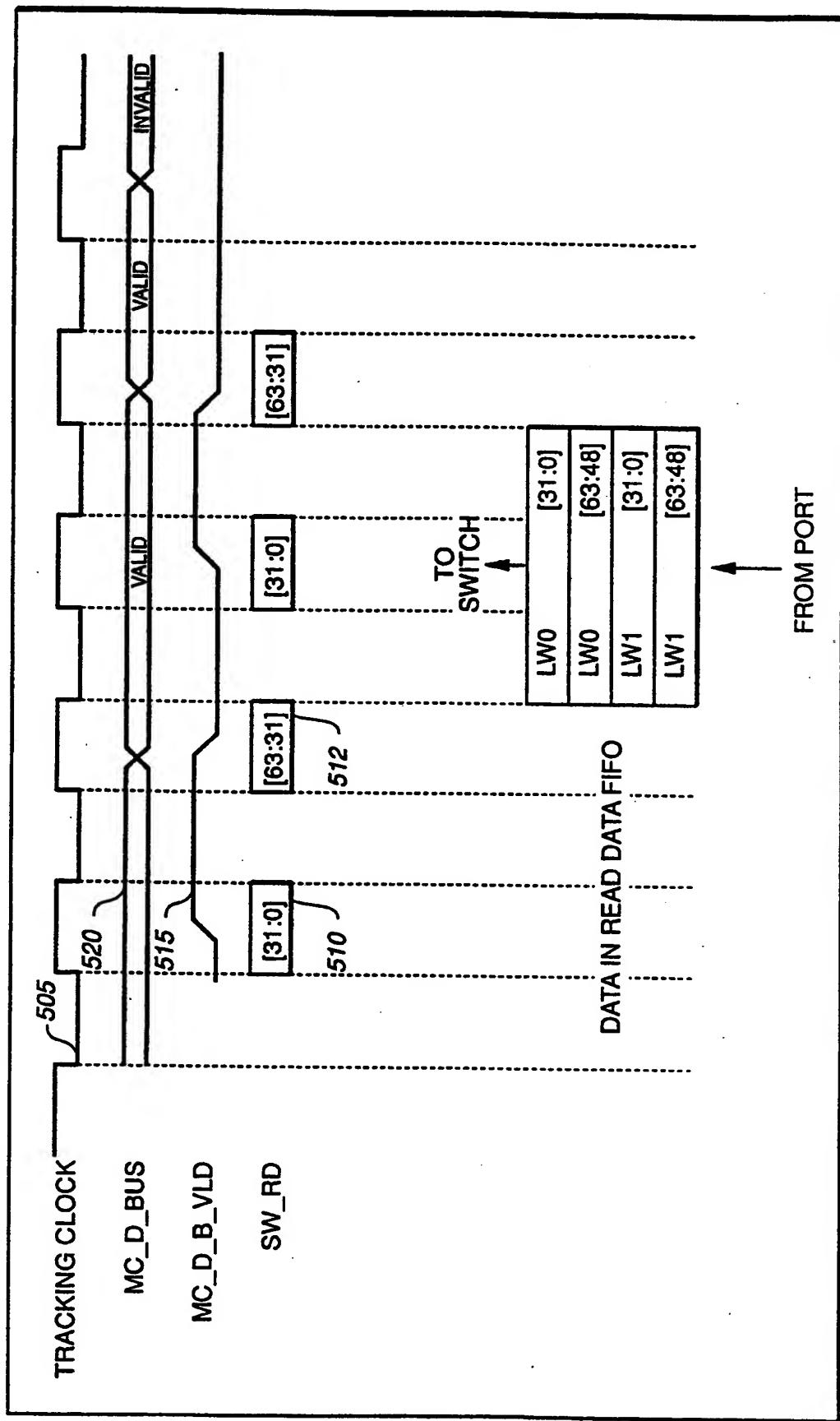


FIG.- 5A

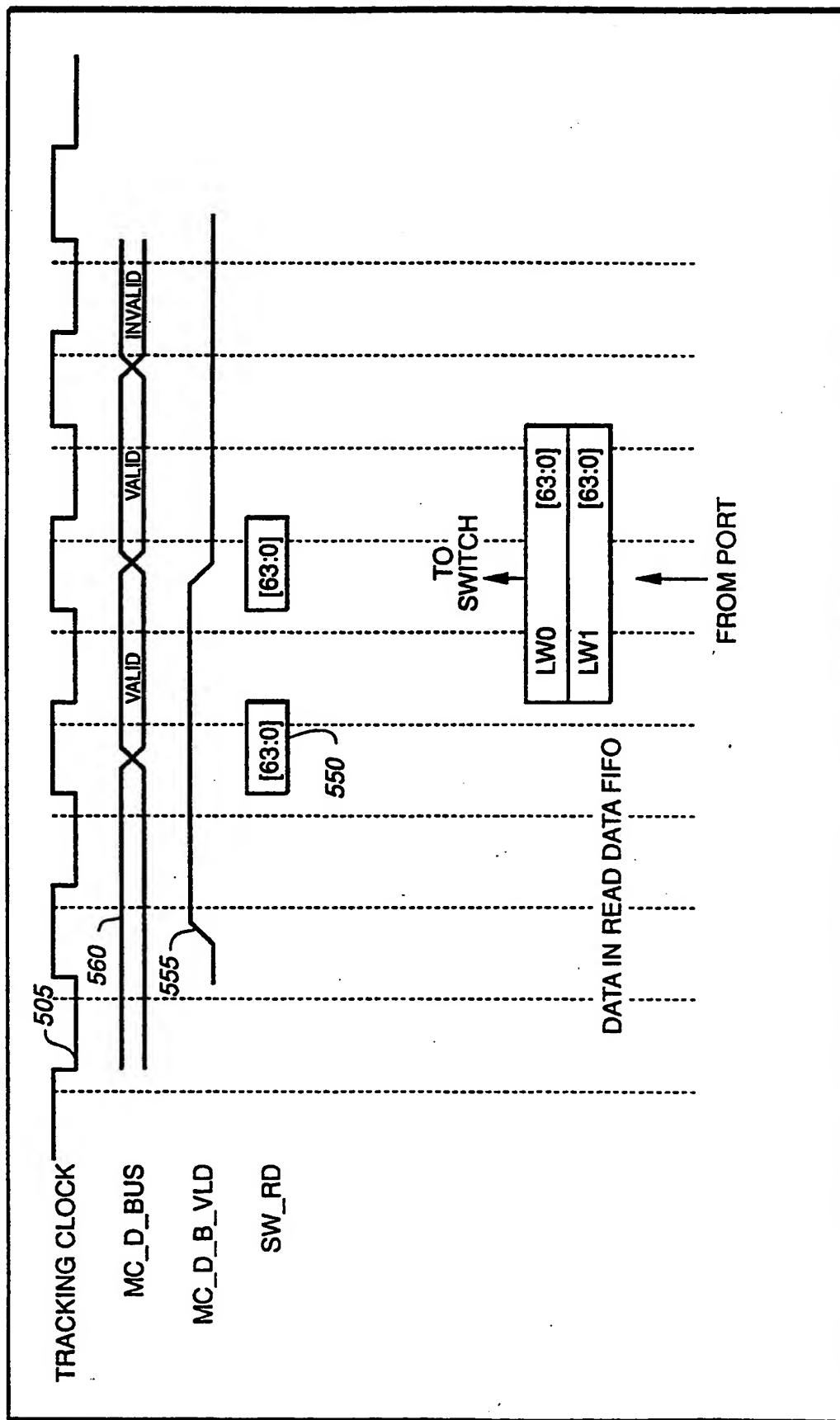
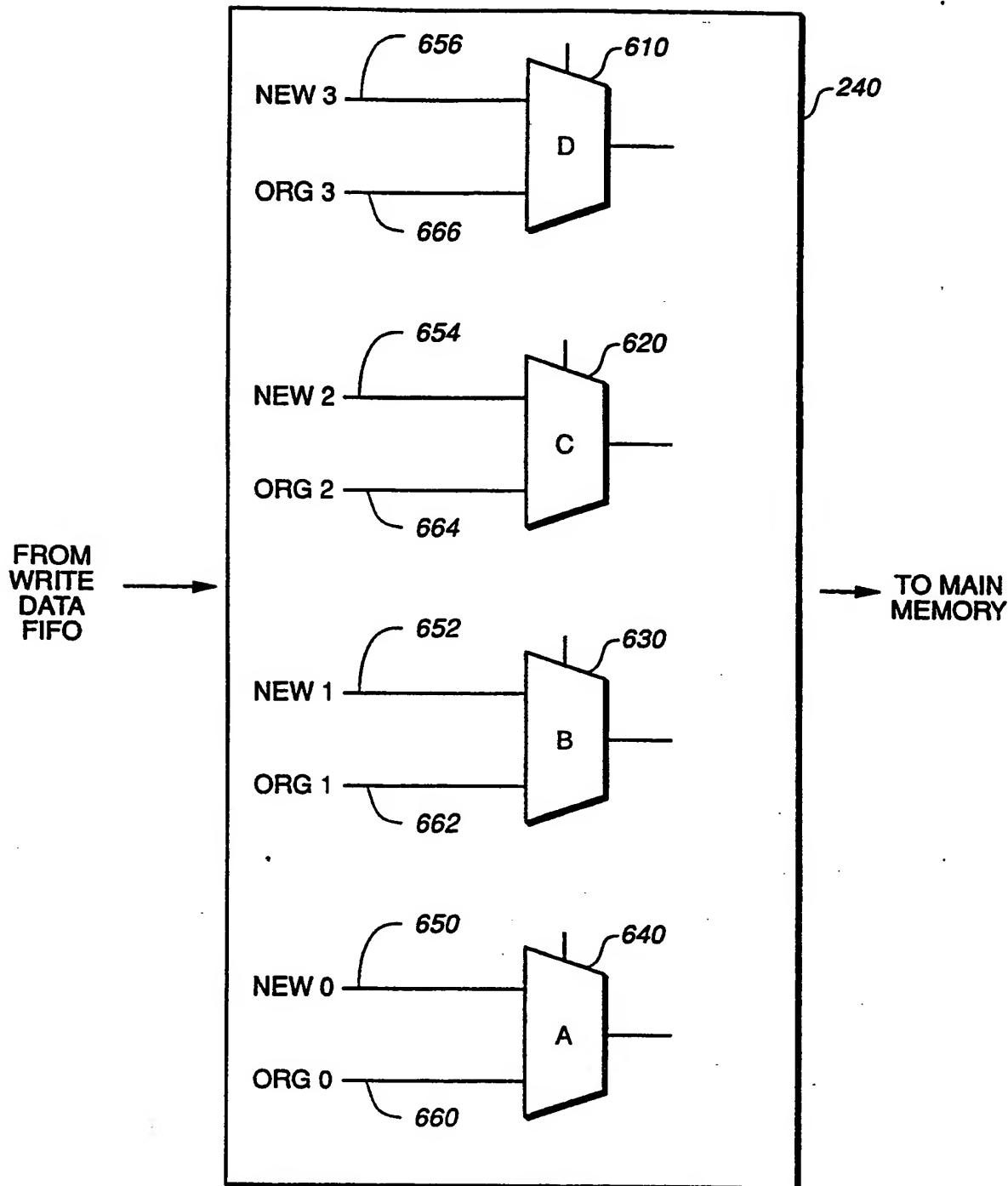
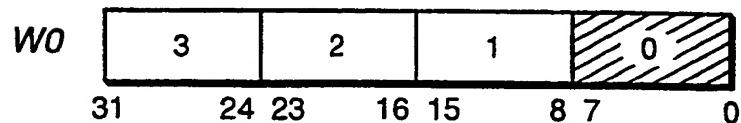


FIG. 5B

**FIG._6A****FIG._6B**

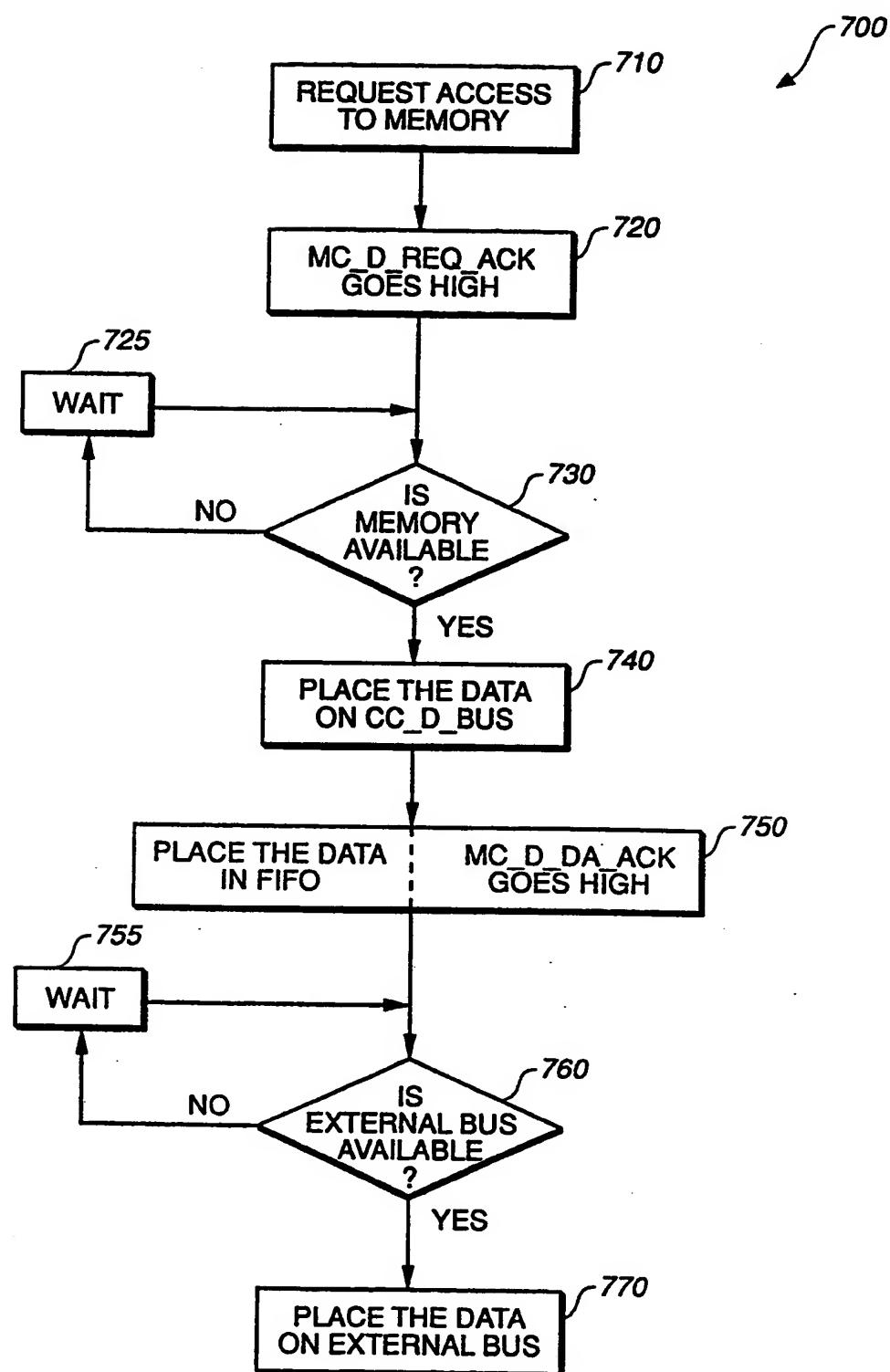


FIG._7

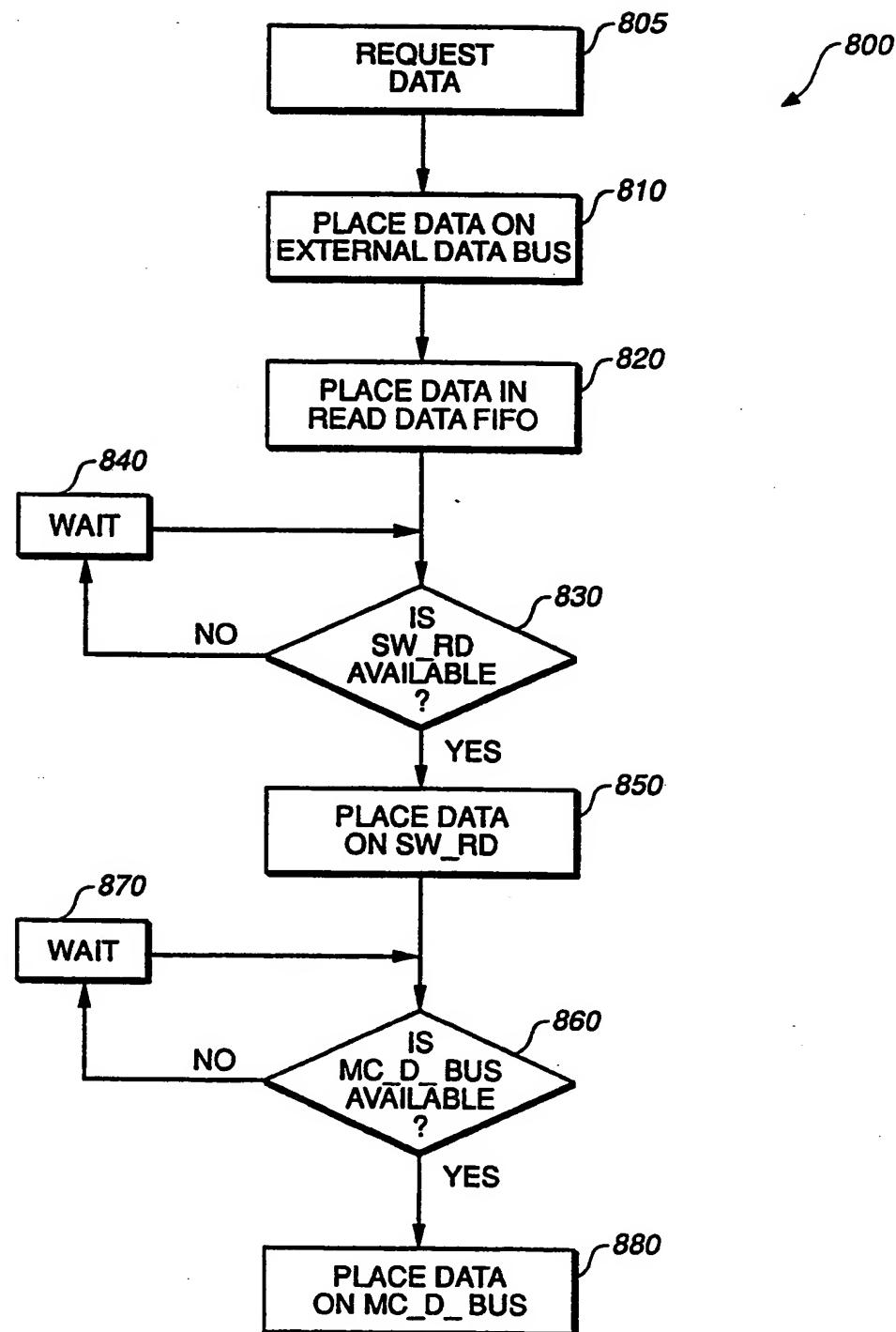


FIG._8

INTERNATIONAL SEARCH REPORT

International Application No.

PCT/JP 93/00317

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)⁶

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.C1. 5 G06F13/40

II. FIELDS SEARCHED

Minimum Documentation Searched⁷

Classification System	Classification Symbols
Int.C1. 5	G06F

Documentation Searched other than Minimum Documentation
to the Extent that such Documents are Included in the Fields Searched⁸III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹

Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
X	EP,A,0 255 593 (INTERNATIONAL BUSINESS MACHINES CORPORATION) 10 February 1988 see column 1, line 50 - column 4, line 11 see column 7, line 45 - line 53 see column 8, line 46 - column 9, line 4 see column 20, line 6 - line 45; figures 1-3 ---	1-4,6-8, 11,13-15
Y	EP,A,0 468 823 (DELL USA CORPORATION) 29 January 1992 see page 4, line 17 - page 5, line 33 see page 14, line 12 - line 44 see page 21, line 2 - line 13; figures 1,4 --- -/-	1-10

⁹ Special categories of cited documents :¹⁰

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- "&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search

24 MAY 1993

Date of Mailing of this International Search Report

11.06.93

International Searching Authority

EUROPEAN PATENT OFFICE

Signature of Authorized Officer

NYGREN P.P.

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
Y	<p>ELECTRONIC DESIGN vol. 33, no. 12, May 1985, HASBROUCK HEIGHTS, NEW JERSEY US pages 219 - 225</p> <p>ZOCH ET AL. '68020 DYNAMICALLY ADJUSTS ITS DATA TRANSFERS TO MATCH PERIPHERAL PORTS' see page 219, left column, line 13 - right column, line 6 see page 221, left column, line 23 - page 222, right column, line 6; figures 1,2 ----</p>	1-10
A	<p>EP,A,0 290 172 (ADVANCED MICRO DEVICES, INC) 9 November 1988 see column 2, line 8 - line 50 see column 3, line 33 - column 4, line 15; figure 2 ----</p>	1,7, 11-15
A	<p>PATENT ABSTRACTS OF JAPAN vol. 12, no. 100 (P-683)(2947) 2 April 1988 & JP,A,62 232 061 (CASIO COMPUTER) 12 October 1987 see abstract -----</p>	1,7,11, 14,15

ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.

JP 9300317
SA 71331

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on

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24/05/93

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
EP-A-0255593	10-02-88	JP-A-	63039072	19-02-88
		US-A-	5014186	07-05-91
EP-A-0468823	29-01-92	None		
EP-A-0290172	09-11-88	JP-A-	63286033	22-11-88

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